

# Power Technology and Alternative Energy Branch

US Army RDECOM CERDEC C2D Army Power Division  
Aberdeen Proving Ground, MD



PTAE - TR - 10 - 01

## Solar Photovoltaic Technology Assessment for Soldier-Portable and Mobile Power

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# Solar Photovoltaic Technology

Assessment for Soldier-  
Portable and Mobile Power



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**Power Sources Conference 2010**

**Wednesday, June 16, 2010 , 3:30 - 5:10 PM**

*Cao Chung*

*US Army CERDEC – Command and Control Directorate –  
Army Power Division*

- Army needs and requirements
- Technologies that address the Army's needs and requirements
- Current development efforts
- Future Opportunities



# Army Applications



- Soldier and Sensor
  - Soldier: Reconnaissance and Surveillance
  - Sensor: Perimeter or Border Security
  - Applicable to 8 hour, 1 day, 3 day, and 7 day missions
  - Need: Prime power and Battery recharging
- Hybrid
  - Remote Power and Silent Watch
  - Tactical Operations Centers (TOC)
  - Need: Fuel savings and Mission extension

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# US Army CERDEC Solar PV Module Level Objectives



All performance metrics reported for AM1.5 insolation and standard, temperature, and pressure (STP) ambient conditions.

	Current	Threshold	Objective	Pacing Technology
Architecture	Foldable Rigid Ruggedized Thin Glint Free* Rollable*	Foldable Flexible Ruggedized Thin Glint Free Rollable Chemically Resistant	Foldable Flexible Ruggedized Thin Glint Free Rollable Chemically Resistant	Packaging Fabrication processes Encapsulation/coating
Power density	35-40 W/kg or 50-80 W/m <sup>2</sup>	40 W/kg or 100 W/m <sup>2</sup>	75 W/kg or 150 W/m <sup>2</sup>	Material selection Novel PV chemistry Encapsulation/coating
Conversion efficiencies	5 to 8 %	10%	15 %	Material selection Novel PV chemistry
Cost	\$15 per Watt	\$3.50 per Watt	\$2.50 per Watt	Material selection Fabrication processes

\*Available for certain current technologies.

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# Various Alternative Energy Technologies



## U.S Army CERDEC has interest in:

- Thermoelectrics
- Wind Turbines
- Waste to Energy
- Heat Actuated Cooling
- **Solar Photovoltaics (PV)**
  - Device construction
  - Energy storage
  - Systems

## Rucksack Enhanced Portable Power System (REPPS)

- Connects to BB-2590 lithium ion rechargeable battery to allow for continuous operation of unattended ground sensors and surveillance cameras
- Flexible panels use copper indium gallium (di)selenide (CIGS) photovoltaic chemistry
- Over 100 systems have been provided via the US Army's Rapid Equipping Force (REF) and US Marine Corps (USMC)
- Recharges BB-2590 in 4 to 6 hours, depending on sun
- Approximately 62-watt peak at AM1.5, 25degC



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- Legacy Silicon PV
  - Mono-crystalline
  - Poly-crystalline
  - Amorphous
- Near Term PV
  - Copper Indium Gallium di-Selenide
  - Cadmium Telluride
- Next Generation PV
  - Organic photovoltaic
  - Dye sensitized solar cells
  - Quantum dot solar cells
  - III-V



Device representation from Bell Laboratory.  
Image courtesy of Kazmerski.

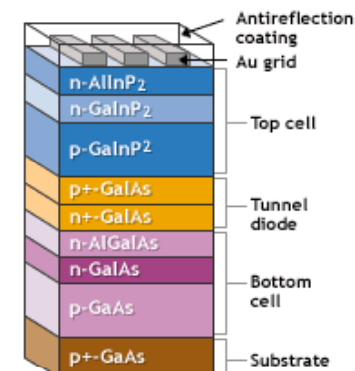


(a)



(b)

Image courtesy of Kazmerski



Multi-junction cell. Image courtesy of EERE.

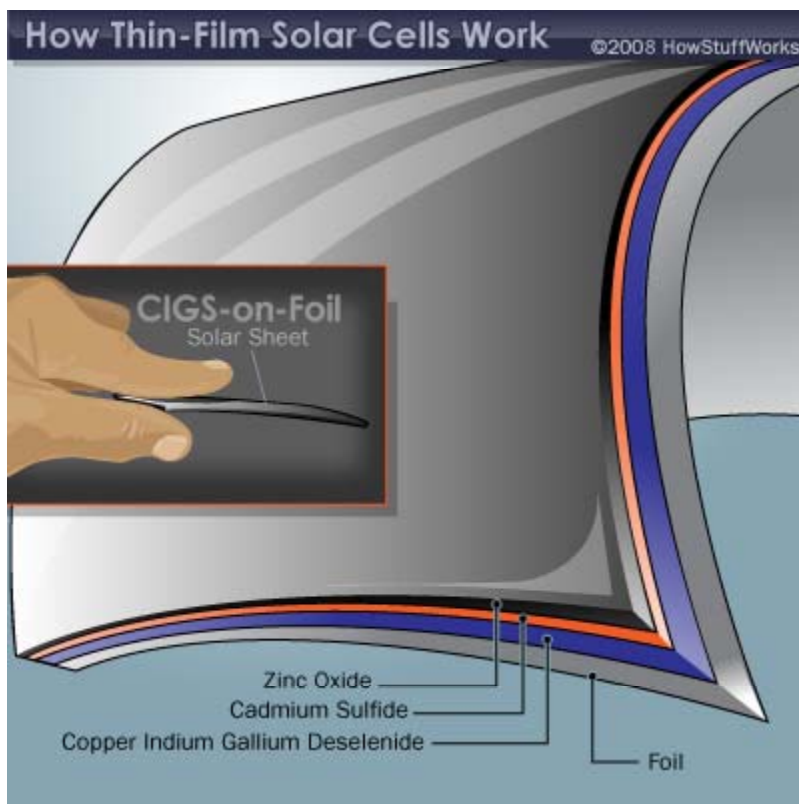


# US Army CERDEC Solar PV Material Focus

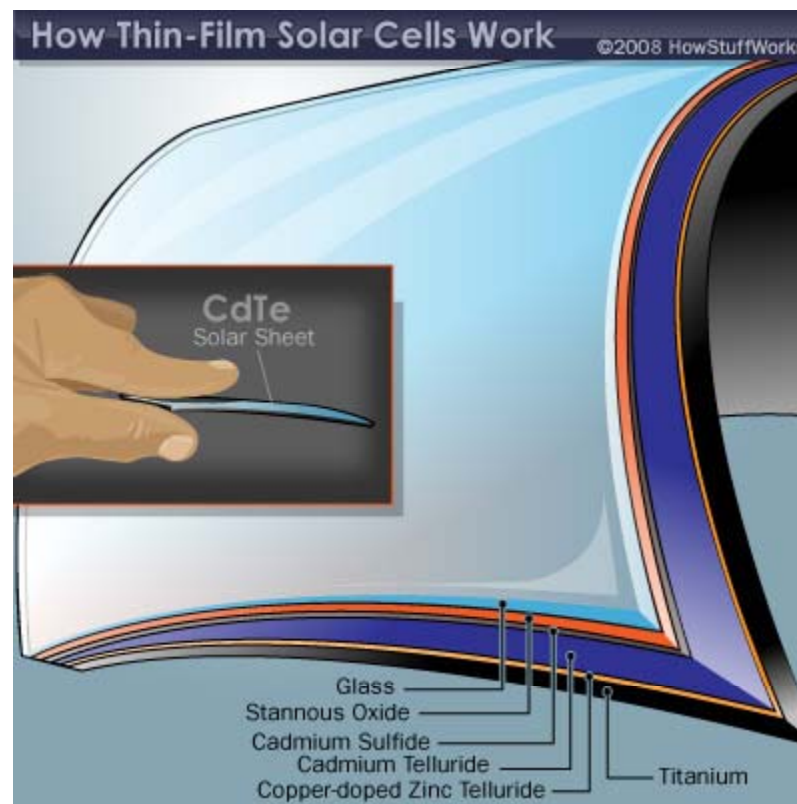


- Copper Indium Gallium Diselenide (CIGS)
  - Efficiency = 17%
  - PVD fabrication
  - Indium
- Cadmium Telluride (CdTe)
  - Cell Efficiency = 16.5%
  - PVD fabrication
  - Health and environmental concerns are alleviated

## CIGS



## CdTe



Images are courtesy of HowStuffWorks.com

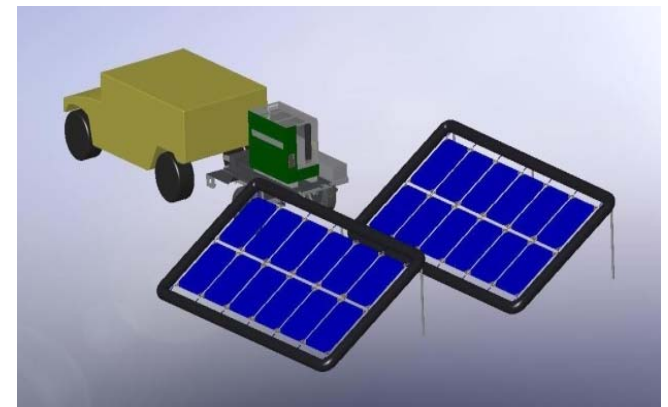
## Portable Micro-Inverters

- 200-watt continuous inverter for rigid and flexible solar photovoltaic panels
- Provides 120-VAC, 60-Hz power that meets utility class 2C power quality per MIL-STD-1332B
- 94% target efficiency and interoperable with most commercial rigid PV panels in the 20 to 40-VDC range
- Capabilities include grid connectivity, islanding and micro-grid modes, and daisy-chaining panels together for additional power generation



## 2.5-kW Advanced Solar Power Source

- Target 15% efficient (threshold 10%) advanced solar PV panels that use cadmium telluride (CdTe) on virtual single crystal (VSC) substrate
- 5-kWe bidirectional inverter that provides 120-VAC single-phase or 208-VAC three phase power at ~90% eff.
- 12-kWh lithium ion battery bank to allow for storage of additional solar power generation
- Demonstration of hybrid system in Spring 2011







# American Recovery and Reinvestment Act (ARRA) of 2009 US Army Flexible Solar Photovoltaic



# RECOVERY.GOV



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# US Army CERDEC Solar PV ARRA of 2009



Reusing Existing Natural  
Energy Wind and Solar  
(RENEWS)

and



Li-ion Energy  
Storage



DC to AC Inverter



Single Box  
System

**Re-  
Transmission  
Sites**

**Command  
Posts**

**Battery  
Chargers**

**Space  
Heaters**

**Communicati  
ons**

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- Technologies Interests
  - Crystalline
  - Thin-film
  - No glass encased devices
- CERDEC's Objective / Focus
  - Power density  $\geq 40$  Watts/kg
  - $\eta \geq 10\%$
  - Cost  $\leq \$3.50$  per Watt
- Applications
  - Inverters
  - Portable Systems
  - Hybrid Systems



- In general, solar technologies show promise to
  - Enhance soldiers mission
  - Decrease logistics
- Opportunities for collaboration
  - Small Business Innovative Research (SBIR):  
Topic #OSD-EP5 (closes 23 June 2010)
  - FY12-15 Army Technology Objectives (ATO's)  
(in planning)
  - Broad Agency Announcements (BAA)  
(in planning)



# Questions?



Thank you for your attention

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# Backup: TRL Definitions



Technology Readiness Level (TRL)	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic (paper) studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in structured or actual field use.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected operational conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended or pre-production configuration to determine if it meets design specifications and operational suitability.
9. Actual system proven through successful mission operations.	Actual application of the technology in its production configuration and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system by operational users under operational mission conditions.

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